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Classroom Photosensor Control System Performance Specification

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Classroom Photosensor Control System Performance Specification

Executive Summary

This report summarizes the functional specifications for a new daylighting control system intended for use in a classroom. This specification has been prepared based upon research conducted as part of the PIER Lighting Research Program Project 3.3.

This specification attempts to solve two primary areas of concern with daylighting control systems. The first priority is to provide accurate control of the electric lights in response to changes in the available daylight. The goal is to maintain the target setpoint while avoiding overdimming or underdimming and any attention causing action. The second priority is to make the setup and adjustment of the control system fast and repeatable. The specification addresses other requirements of a daylight responsive control system, which includes providing a means for occupant adjustment as well as working with common lighting configurations.

Introduction

The purpose of Project 3.3 of the PIER Lighting Research Program is to develop an improved photosensor for daylight responsive dimming for a classroom application. The Watt Stopper (TWS) is conducting this research project, which is funded by the California Energy Commission and managed by Architectural Energy Corporation.

Earlier work in this project has entailed testing by LBNL of The Watt Stopper's existing photosensor, the LS-201. It also included a review of the state of the art in existing photosensors. Ongoing work in this project includes research by Dr. Richard Mistrick of Penn State University on the daylighting performance of typical classroom designs. Dr Mistrick has completed a series of computer simulations of the daylighting and electric lighting performance in these classrooms. The conclusions on photosensor design from his study have been incorporated into this specification.

In May, TWS held a roundtable with a group of industry experts. The 32 attendees included architects, electrical engineers, lighting designers, daylighting consultants, utility representatives, researchers and TWS senior managers. TWS presented the preliminary version of the control system concept and received a very positive response. Providing better daylighting products as well as better application tools were very important to the group. Overall, the four priorities were:

a. simplified installation
b. simplified setup and testing
c. integrated occupant adjustment capabilities
d. tools for providing information to commissioning agent

This specification has been written to incorporate these priorities as well as the other ideas developed during the research for this project.

This specification is particularly focused on solving the daylight portion of the problem and does not intend to address all of the lighting control functions that may be desired in a classroom.

This specification is intended to address the daylighting control issues involved with a classroom with windows. Sidelighting presents more challenges for daylight responsive control than a toplit application. However, this specification is also intended to provide a good solution for a toplit application. Similarly, while focused on classrooms, this design is also likely to provide a good solution for daylighting responsive control in both open and private offices.

This specification presents a solution to work with standard 0-10 volt dimming ballasts. While it is beyond the scope of this project, the concepts and tools used in this project would be applicable to providing daylighting control for other types of dimming ballasts including DALI ballasts. In many ways, the loosely defined 0-10 volt standard presents additional challenges that would not be found in other dimming standards.

System Configuration

The daylighting responsive control system concept presented consists of four control devices. It uses low voltage wiring to simplify the installation of these devices, and wireless communication to simplify the setup and calibration of the control system. The first component is a power pack. The power pack provides two key functions. The first function is to provide a source of low voltage power to provide power to the photosensor. The second function is to provide a means of switching the line voltage power supplying the controlled electric lights in the classroom. The power pack is typically mounted above the ceiling and contains both a power supply and a relay. The second component is a photosensor. The photosensor is designed to be ceiling mounted. The photosensor reads the light level in the classroom and commands the lights to provide the appropriate light output. The third component is a desktop tool that is used at startup to automate the setup and adjustment of the device. The fourth component is an occupant adjustment control. In this specification, this device would be a wall switch that would allow the occupants to turn the lights on and off, or to raise and lower the target light level. In addition, it is assumed that in many applications, particularly classrooms, this daylighting responsive control system will be used in combination with one or more occupancy sensors.

Description of Hardware

Power Pack

The power pack is the single point of connection to the line voltage wiring. All of the control devices interface to the line voltage wiring at this point. All of the control wires emanating from the power pack shall be low voltage.

The intent of this specification is to use an existing commercially available power pack manufactured by The Watt Stopper, the BZ-100E-P. The intent is to leverage the resources available for this project by adapting an existing product.

TWS proposes to modify the commercially available device to add quick connectors so the installation of the new control system is simplified. Terminations of multiple wires that would require the correct matching of pairs of wires would be replaced by plugging together two or more connectors. One possible complexity is that in addition to the photosensor to power pack connections, occupancy sensors to power pack connections must be made.

In most classroom situations in California, a power pack is part of the base design because occupancy sensors are required by Title 24 with the generally accepted best coverage provided by a ceiling mounted occupancy sensor. Most ceiling mounted occupancy sensors require the use of a power pack. This same power pack can be used for the photosensor as well as for one or more occupancy sensors.

The selected power pack can be connected to either 120 or 277 VAC. It does not need to be specified for a specific voltage, thus requiring one less specifying and purchasing decision.

This power pack also provides additional signal inputs not typically found in a power pack that simplify the wiring connections in this application. A typical power pack has only one control input, typically connected to an occupancy sensor. The occupancy sensor signals the power pack on this input to turn lights on and off. The selected power pack has two additional signal inputs that have a higher priority than the occupancy sensor input. One of the inputs is Force On. When this input is signaled, the power pack switches the lights on even if the occupancy sensor indicates the room is no occupied. The other signal input is a Force Off. When this input is signaled, the lights are switched off even if the occupancy sensor indicates that the room is occupied. The control function in this application of these two high priority inputs will be described in the operation section of this document.

Photosensor

The photosensor shall be designed for mounting either on the ceiling or integrated into a pendant lighting fixture. The photosensor shall use a microcontroller to provide the operating intelligence for the control system. The photosensor is designed to provide control for one zone of closed loop control daylight responsive dimming control.

All setup and adjustment required following installation shall be done remotely from the photosensor. All adjustment parameters shall be stored in non-volatile memory such that these parameters shall not be lost if power is removed from the photosensor.

The photosensor shall be powered by the low voltage power supplied by the power pack.

Photosensor Inputs

Light Level Measurement

A photodiode shall be used to provide a light level measurement that can be correlated to the desktop illuminance. The photodiode shall be optically filtered to measure light to closely match the human photopic response. This corrected response shall solve the problem of over reporting the illuminance provided by daylight.

The photodiode shall be housed in an enclosure that reduces the photodiodes light receptivity to a 110-degree cone of view (55-degree half angle). While freely admitting light within this cone, it shall block nearly all of the light from angles beyond this cone of view. This sharp cutoff of the light shall be useful in blocking light received from windows and pendant fixtures. This sharp cutoff shall provide flexibility in installing in proximity to windows or pendant fixtures. The cone of view is wide to reduce the response to changes in reflectivity caused when objects or individuals enter the viewed area. By viewing a larger area, the impact of an individual object shall be reduced. Also, this larger cone of view shall be beneficial for applications where the photosensor's distance from the task surface is reduced. For example, when the photosensor is integrated into a pendant fixture, its mounting height is reduced and its distance from the task surface is reduced thus reducing the solid surface viewed by the photosensor.

The full scale of the light level measurements shall be scaled as found appropriate for the application. The range is initially defined as a light level reading corresponding to a ceiling illuminance range of .1 to 400 footcandles. Within this range, the resolution of the light measurements shall be greatest at the lower light levels and decrease as the light level increases. The range of light level measurements is extended well beyond the normally anticipated control range to facilitate setup and adjustment over a range of daylit conditions. Also for the same reason, the resolution over this range is also far greater due to the precision required for two reasons. The first is for calibration when changes in illumination from electric light may have to be measured at a time when a great deal of daylight is present. The other reason is to the photosensor to work with indirect lighting utilizing pendant fixtures. These fixtures direct their light primarily up to the ceiling to reflect and distribute light to the illuminated area. The result for the photosensor is that the ceiling illumination is greatly increased. With this elevated range, it is still critical to be able to resolve changes in task illuminance from daylight even though the magnitude of the signal change may be small in relation to the overall light level signal.

<u>Sense Control Signal</u>

The photosensor shall read the 10 VDC signal supplied by the ballasts to the photosensor as well as the resulting 0-10 VDC dimming signal. The maximum voltage supplied by the ballasts should never be expected to exceed 16 VDC. The resolution from 0-10 VDC should be .05 VDC or greater. The maximum required scaled reading is 12 VDC.

<u>Occupant Adjustment – On/Raise</u>

This input shall be connected to a wall switch used for occupant control and adjustment. The wall switch shall be connected to the photosensor by three low voltage wires, one for the On/Raise, one for the Off/Lower, and a common wire.

A contact closure of ½ second or less shall be interpreted as a request to turn on the lights. After ½ second of closure, the signal shall be read as a desired amount of light increase. The lights shall continue to rise for the duration of the contact closure.

<u>Occupant Adjustment – Off/Lower</u>

This input shall be connected to a wall switch used for occupant control and adjustment. A contact closure of ½ second or less shall be interpreted as a request to turn off the lights. After ½ second of closure, the signal shall be read as a desired amount of light decrease. The lights shall continue to dim for the duration of the contact closure.

Photosensor Outputs

<u>Dimming Control Signal</u>

The dimming control signal shall operate by providing a variable resistance to modulate the control voltage sourced by the ballasts. The range for the control signal shall be from 0 – 10 VDC with a maximum supply of 16 VDC.

The maximum range of current shall be from .2 to 20 mA. This range of current corresponds to the requirements anticipated from controlling one standard dimming ballast up to a maximum of 30 ballasts equivalent to an Advance Transformer Mark VII.

The voltage level of the control signal shall be able to be stepped by increments of .1 VDC or less, providing a minimum of 100 steps of control over the ballast range.

<u>Force On Signal</u>

The photosensor shall have a control relay rated to switch a 24 VDC signal. This control relay shall be used to signal the power pack to switch the controlled lights on. This signal shall be transmitted over low voltage wires to the power pack.

<u>Force Off Signal</u>

The photosensor shall have a control relay rated to switch a 24 VDC signal. This control relay shall be used to signal the power pack to switch the controlled lights off. This signal shall be transmitted over low voltage wires to the power pack.

Installation Note:
All electric lights controlled by the photosensor shall have to be switched by one power pack to provide the functionality described.

<u>Status LEDs</u>

The photosensor shall have a minimum of two onboard LEDs to provide various status indications.

Photosensor Communication Ports

<u>Wireless Communication</u>

The photosensor shall communicate over wireless communication with the desktop tool. Communication shall be bi-directional. The maximum required communication distance shall be 25 feet. Only line of sight communication is required.

Future versions will likely require address specific communication to allow individually addressing a photosensor in an area with multiple photosensors.

<u>Communication Port</u>

For programming and testing, this device shall have a serial port.

Future versions would likely replace the serial port with another type of communication port to be used for manufacturing purposes only.

Desktop Tool

The desktop tool is a portable tool intended for setup and calibration by the installer. It is intended that only one desktop tool would be required for a building with potentially hundreds of photosensors. The desktop tool may also act as an information source for a commissioning agent aiding in their creation of a commissioning report.

The desktop tool shall direct the setup process as well as contain the processing power required for the calibration calculations. The desktop tool is intended to sit on the task surface and measure task level illuminance. Placing it on the task surface puts it at a height that can be documented as well as allowing the setup agent to step away and not block the light seen by the photocell. While portable, it is not intended to be a handheld device.

The primary goal of the desktop tool is to simplify the setup and calibration process. It directs an automated process to determine the photosensor signal to task illuminance ratios for both the controlled electric lights and for daylight. By automating this sequence and resulting calculations, it is intended that the setup and adjustment for the photosensor be completed in one short duration action.

The desktop tool shall differentiate the calibration process from the setup process with the intent that both could be completed at one time under most daylit conditions. The calibration process shall equate the photosensor signal to the task illuminance by sharing illuminance information from the task level with the photosensor.

The adjustment process shall include the entering of target illumination setpoints and other operating characteristics. The desktop tool shall be designed to facilitate repetitive commissioning by organizing these adjustment parameters into “profiles” which may be selected and reloaded in a single step.

It is envisioned that future versions shall operate on a battery to provide greater portability. However, prototype versions shall be powered by an external power supply. Battery operation shall require power management engineering not necessary for the proof of concept.

No work will be done at the prototype stage on designing an enclosure or in attempting to fit all of the components within the intended enclosure size.

Desktop Tool Inputs

Light Level Measurement

A photodiode shall be used to provide a light level measurement that corresponds to the desktop illuminance. The photodiode shall closely match the spectral response of the photosensor’s photodiode.

The photodiode shall be covered by a plastic enclosure and a light transmitting diffuser, combining to provide a cosine corrected response.

The full scale of the light level measurements shall be scaled as found appropriate for the application. The range is initially defined as a light level reading corresponding to a ceiling illuminance range of .2 to 400 footcandles. Within this range, the resolution of the light measurements shall be greatest at the lower light levels and decrease as the light level increases.

Desktop Tool User Interface

The desktop tool shall have a display screen used to display task illuminance readings as well as allow user adjustment to the photosensor setup parameters. Display shall have a minimum of two rows with a minimum of 24 characters.

There shall be four buttons for a user to select menu options or to raise or lower the light level. The function of the buttons shall change with the context, but shall raise target setpoint, lower target setpoint, next, and enter.

Initial versions of the prototype may use a laptop computer to simulate the desktop tool's onboard display screen. Future versions of the desktop tool will provide a fully functional display.

Desktop Tool Communication Ports

<u>Wireless Communication</u>

The desktop tool shall communicate over wireless communication with the photosensor. Communication shall be bi-directional. The maximum communication distance shall be 25 feet. Only line of sight communication is required.

Future versions shall likely require address-specific communication for applications in which multiple photosensors are located within one open space such as a library or office.

<u>Communication Port</u>

For programming, this device shall have a serial port.

A future version shall likely have a USB port for downloading setup and calibration reports to a personal computer.

Occupant Control

The occupant control shall be provided by a wall switch. The wall switch shall have two momentary buttons. One button shall provide on or raise control, depending on the current state of the lights and the duration of the press. The other shall provide off or down control.

Existing available wall switches shall be identified and utilized for this prototype. Methods for adding modular connections shall be explored to simplify the wiring.

Future versions may include a wall switch that provides a visual indication of the override status when an occupant attempts to adjust the light level.

Description of Operation

Operating Mode

<u>Photosensor Light Level Measurement</u>

Light level measurements shall be averaged to minimize reactions to transient conditions.

The photosensor shall use the light level reading in combination with the dimming signal reading to calculate a more accurate approximation of task illuminance. The electric light contribution is calculated by using the electric light reference table to determine the electric light illuminance and the equivalent light level signal expected from the lights when commanded to the dimming level. Next, the daylight illuminance is calculated by finding the remaining light level signal and multiplying this value by the daylighting task illuminance to photosensor ratio.

This integrated logic will also include error checking. For example, if the total light level signal is not equal to or greater than the expected electric light illumination then there is a problem. One possible application of this error checking would be to defeat the common tactic of taping over the photocell to defeat the dimming control. When the light level reading is equal to or near zero at the same time that the dimming control signal was present, then the dimming control signal could be commanded to minimum.

In addition to greater accuracy, the ability to differentiate daylight and electric light shall allow the photosensor to be mounted on the ceiling in applications with direct/indirect pendant lighting fixtures. Mounting a photosensor in proximity to this type of fixture can present the inverted from normal relationship where the light level signal at the photosensor decreases as the daylight increases and the electric lights dim. With the photosensor able to differentiate light sources, the photosensor can utilize the calculated daylight illuminance for its critical variable.

Monitoring Dimming Control Voltage

The dimming control signal shall be monitored both to provide feedback for normal dimming control and to provide exception reporting. An example of an exception is when another control device such as an occupancy sensor switches off the controlled lights. This exception would be indicated by a control voltage at or near zero, because the power to the ballasts has been switched off. Receiving indication of this exception is important for the photosensor operation for several reasons. First, it is important to avoid overshooting the desired light level when the controlled lights are switched back on. The control function can be further enhanced by having the electric lights ramp up when switched back on. The second key reason for monitoring this signal is to lock out the automated calibration process if the controlled lights are not switched on or properly connected to the photosensor.

Dimming Control

The photosensor shall utilize sliding setpoint control with a separate night, or electric light, target setpoint and a separate daylight, or full dimming, target setpoint. The daylight illumination target setpoint is limited to be no less than the electric light target setpoint, but may be higher if desired for the application. Having a higher daylight setpoint would allow the overall task illumination to rise before the electric lights are fully dimmed.

The electric light target setpoint shall allow the reduction of the electric lights from their full output. This capability, sometimes referred to as "tuning", shall provide energy savings. In addition, because the system is attempting to maintain illumination levels, the illumination levels shall be maintained automatically over time thus compensating for lumen depreciation.

In addition, it shall be possible to set a minimum dimming control signal. The minimum dimming control signal shall be the minimum signal even when the daylight task illumination is greater than the target setpoint. The minimum illumination level shall be maintained automatically over time thus compensating for lumen depreciation.

The control response shall provide a fast ramp up and slow dim down strategy to minimize the occupant's awareness of the dimming control. This strategy shall error toward providing too much light, while reducing the chance that the task illuminance can drop below the target setpoints.

The dimming signal shall be updated under steady state operation no more frequently than once every 30 seconds. During periods of transition, the updates may be more frequent. When the light level is far away from the target setpoint, predictive control shall be used based on the reference lookup table. The dimming control signal that produces the desired illumination shall be identified and then sent to the controlled lights. When the light level is close to the target setpoint, incremental control shall be used. If the light level is below the target, the dimming control signal shall be stepped up until the desired level is reached. Conversely, if the level is too high, then the dimming control signal shall be reduced in small increments.

<u>On/Off Control</u>

If selected at setup, the photosensor shall command the lights off when there is sufficient daylight. There shall be an adjustable time delay for this to occur. This control shall utilize the Force Off signal to override a possible indication of occupancy. This signal shall remain present even if occupancy is terminated. When it is determined that the daylight task illuminance has dropped sufficiently, then the lights shall be allowed to turn back on by removing the Force Off signal.

An occupant shall be allowed to switch off the lights by pressing the off button on the wall switch. Pressing off shall turn on the Force Off signal. Pressing on shall turn off the Force Off signal. If the daylight illuminance drops, then the Force Off signal shall be released allowing the lights to turn back on. (Note that with the lights forced off, it shall not be possible to monitor if the lights have been switched off due to the termination of occupancy.)

The lights shall normally automatically turn on when occupancy is resumed, except if there is sufficient daylight. However, if the lights have been commanded off because daylight is considered sufficient, they will not automatically switch on when occupancy is resumed. However, pressing the wall switch shall allow the lights to temporarily override the lights on. The Force Off signal shall be turned off. When occupancy is terminated, if Force Off had been overridden off, then it shall be turned back on.

During the automated setup and calibration process, the Force Off and Force On commands shall be used to first turn off the lights and then turn them back on and ensure that the controlled electric lights remain on during the calibration process.

To create a reference table for electric light illumination, the photosensor may turn on the lights during an unoccupied nighttime period. To accomplish this test, the Force On command shall be used.

<u>LEDs</u>

An LED shall flash rapidly until the photosensor has been setup. Any time that the photosensor is returned to its factory defaults, the LED shall flash.

An LED shall also flash whenever the desktop tool is communicating with the photosensor.

Occupant Adjustment

In addition to being able to switch the lights on and off with a wall switch, an occupant shall also be able to raise or lower their target illuminance setpoint.

By pressing the Raise button for longer than ½ second, the electric lights shall rise at a rate fast enough to observe. The lights shall continue to rise for as long as the button is pressed or until the maximum allowable level has been reached. Similarly, if the Lower button is pressed for longer than ½ second, the electric lights shall lower at a rate fast enough to observe for as long as the button is pressed. While providing feedback to the occupant with an observable change in illuminance, the photosensor is also making an internal calculation of the magnitude of the adjustment. This calculation creates a numerical offset used to raise or lower the target setpoint. This offset shall remain active when the daylight illumination changes. It will be used to calculate a new target setpoint using the new daylight information as well as the user adjustment offset. The magnitude of the allowable user adjustment offset shall adjustable at startup.

Setup and Calibration

The sequence of events in the setup and calibration mode shall be directed by the desktop tool. The desktop tool shall act as the master and the photosensor shall be the slave. (The one exception to this is if, in the final design, it is determined that the photosensor shall create an electric light reference table during an unoccupied period.)

Setup shall consist of two distinct operations: parameter setup and calibration. Parameter setup shall consist of adjusting the operating characteristics of the photosensor. Calibration shall involve calculating the task illuminance to photosensor ratios unique to each space. Typically, parameter setup is completed first and calibration is second. It is also recommended that any time a target setpoint is changed that the calibration be redone.

Setup and calibration shall be completed in one visit. Setup and calibration is to be allowed when the daylight illuminance on the task exceeds the target illumination setpoint. The automated process is to take five minutes or less on average per photosensor.

Setup

The following parameters shall be displayed on the user display of the desktop tool. It shall be possible to press a button to scroll through the parameters and select an individual parameter to adjust. Alternatively, the parameter setup process could be bypassed by using either the factory default settings or by reloading a previously saved profile. It is anticipated that on a given project that the profiles, or collection of setup parameters, are reusable for most photosensors.

These parameters may be entered under any lighting conditions. If the parameters are adjusted individually (as opposed to reusing a profile), then the adjusted value is transmitted from the desktop tool to the photosensor when the new parameter has been entered.

The units for the target setpoints directly represent desired footcandles on task. These target levels are independent of room specific conditions such as room finishes, furniture placement, and lighting fixture type. The benefit in this scheme is that the target setpoints are fully portable, being moveable from room to room. During the calibration of each photosensor, the room specific conditions are measured and used to convert the target setpoints into operational setpoints.

Nighttime Setpoint

This is the target illuminance setpoint when there is no daylight contribution. The units for this parameter are footcandles at the task level. The factory default for this parameter is 35 footcandles. Pressing the up or down buttons on the desktop tool will scroll through a range of setpoint choices from 20 footcandles to 50 footcandles in one footcandle increments. Making this adjustment does not cause the lights to raise or lower.

Daytime Setpoint

This is the target illuminance setpoint when the electric lights are dimmed to their minimum. The units for this parameter are footcandles at the task level. The factory default for this parameter is 45 footcandles. This parameter is to be range limited to be no lower than the nighttime setpoint and no greater than twice the nighttime setpoint. Pressing the up or down buttons on the desktop tool will scroll through a range of setpoint choices in one footcandle increments starting from the electric light setpoint. Making this adjustment does not cause the lights to actually raise or lower.

Minimum Electric Light Setpoint

This is the minimum illuminance setpoint provided by the electric lights to be maintained when the total illuminance equals or exceeds the daytime setpoint. This parameter is important for working with lamp and ballast combinations which flicker or go off at lower signal levels as well as to satisfy the design intent to have electric lights to always appear to be illuminated. This parameter is also useful in avoiding situations where other design factors can cause a situation where despite bright light in one portion of a zone, another portion of the zone is too dark. The units shall be footcandles on the task level. The factory default for this parameter is zero, allowing the electric lights to fully dim. Pressing the up or down buttons on the desktop tool will scroll through a range of setpoint choices in one footcandle increments starting from zero. Making this adjustment does not cause the lights to actually raise or lower.

Daylight Off Delay

This parameter enables the electric lights to switch off when there is sufficient daylight or disables this function and does not allow the lights to switch off automatically due to an abundance of daylight. If enabled, then two options shall be available for the duration of the time test. The first, and factory default, is 10 minutes. If the electric lights remain at the minimum electric light setpoint for 10 minutes, then the lights shall be commanded off. The second option is for a long time test of 20 minutes.

Daylight On Delay

This parameter is only used if the daylight off delay is enabled. This is a time test for the electric lights to turn back on. If the daylight level falls sufficiently for the length of time set, then the electric lights shall turn back on. The options for this setting are 15 seconds, 30 seconds and one minute. The default is 30 seconds.

User Adjustment Authority - Reduce

This parameter sets the maximum limit that an occupant can reduce their target setpoint. The choices shall be 100, 50, 25, or 0 percent. The default setting is 100 percent allowing for full reduction.

User Adjustment Authority – Increase

This parameter sets the maximum limit that an occupant can increase their target setpoint. The choices shall be 100, 50, 25 or 0 percent. The default setting shall be 40 percent.

Duration of User Adjustment

This parameter defines whether the user adjustment resets to the primary setpoint or continues to remain active until an additional adjustment is made. The options for this parameter are "terminate when lights are switched off" or do not terminate.

Responsiveness

This parameter shall define the responsiveness of the control function. This is a parameter that shall be further defined in the future as needed for some applications. It is anticipated that for some applications, perhaps with adjoining dimming zones, that the responsiveness of the control would be required to be reduced.

Set Address

The photosensor address shall be settable from one to 255 for purposes of correspondence with building documents and setup reporting. It shall be possible to assign each photosensor one of a possible 255 addresses. Each photosensor can then be queried as to its address. Furthermore, this address shall be used for report generation. When the adjustment parameters, as well as the calibration data, is saved from each photosensor, the data shall be stored in sequence by the photosensor's address. The default address shall be 255.

This function shall not be fully implemented in the proof of concept stage.

Store Settings into a Profile

The adjusted setup parameters shall be able to be stored into one of two profiles to facilitate repetitive commissioning.

Reload Profile

Either profile 1 or 2 can be selected to reload into the photosensor, thus automatically configuring the photosensor.

Service Functions

The following section describes other functions that provide information useful for testing and commissioning.

User Display

The default display on the screen shall be the desktop illuminance displayed in footcandles. This value shall update once a second.

During calibration, the screen shall display only a calibration in process message. This message shall encourage the person using the tool to step back and not block light from the desktop tool. If an error occurs, the error message shall be displayed on the screen.

When any button is pressed after a period of inactivity, a menu of choices shall be displayed listing the options of setup, calibrate, or service.

Burn-in Timer

Activating the burn-in timer shall override the lights to full output for 100 hours. It shall also be possible to cancel the remaining portion of the burn-in period and resume normal operation.

This function shall not be fully implemented in the initial version.

Manual Control

It shall be possible to manually turn off and on the lights as well as ramp them up and down for testing purposes from the desktop tool. The lights shall be able to be operated over the entire control range.

This manual control does not change any target setpoints.

Manual control is relinquished after a maximum of one hour of inactivity from the desktop tool. Normal control is resumed.

Read Status

It shall be possible to request status information from the photosensor. Information that may be requested from the photosensor and displayed includes the electric light illumination, the daylight light illumination, the dimming control signal, and the occupant adjustment offset.

Restore to Factory Defaults

It shall be possible to restore the default settings to the photosensor. This step should require an initial selection as well as a secondary confirmation.

Bypass Off Delay Timer for Testing

For use at setup and testing, it shall be possible to bypass the Off Delay timer for a period of one hour. When bypassed, the Off Delay timer shall be reduced to 20 seconds. At the end of one hour, the normal Off Delay shall resume. It shall be possible to cancel the bypass and resume the normal Off Delay sooner.

Save Setup and Calibration Information for Report Generation

It shall be possible to download from the photosensor all of the parameter settings as well as all of the calibration information. Calibration data shall include the daylight illumination at the time of the calibration as well as any error messages.

Note that this operation is a download operation only. There is no provision for reloading the calibration data into the photosensor because of the potential to misuse this feature. The downloaded information should never be used to bypass calibrating a photosensor. Instead, a profile of parameter settings may be reloaded to the photosensor and then the system may be calibrated.

Download information shall be organized in the desktop tool by the virtual address of the photosensor. Information from up to 255 photosensors shall be able to be stored in the desktop tool.

Future versions of the control system may record a date and time stamp in the photosensor recording when the calibration was completed. Future versions may provide a template to provide a formatted report for each photosensor from a personal computer

Calibration

Calibration refers to measuring the room specific characteristics that influence the relationship between the task level in the room and the photosensor on the ceiling. Calibration is an automated process that captures and calculates the task illuminance to photosensor ratios independently for the electric lights and for daylight.

Calibration for every photosensor shall be mandatory.

The calibration process is directed by the desktop tool. For each of the steps, the desktop tool commands the photosensor to take an action such as turning on or off the controlled lights or commanding them to a specific level of dimming. It then requests the photosensor to take a light level reading and transmit it. It then matches the light level reading with a corresponding reading of its own and calculates the ratio between the readings. When complete, the desktop tool then transmits the results of the calculations to the photosensor for use as a “task to photosensor” conversion factors.

During the calibration process, the conversion factors are also used to convert the target setpoints from the units representing task level illuminance into the equivalent photosensor light level values.

An additional aspect of calibration is to measure and record the illumination provided by the controlled lights over the dimming range. This information is used by the photosensor to calculate the expected amount of the illumination contributed by the electric lights. However, the illumination provided cannot be represented by one factor or equation because these ballasts do not dim over the entire 0-10 V range. The solution to this problem is to build a reference or lookup table to record the light output at each dimming level. The principle is that for every control voltage sent to the ballast there is a predictable and repeatable task illumination with a corresponding sensor signal (with an estimated 15 percent of repeatability due to operating temperature and age of the lamp. The actual repeatability will be identified for typical lamps during the testing phase.)

During the calibration process using the desktop tool, the electric lights shall be commanded to at least a minimum number of dimming levels. The photosensor light level and the desktop tool light level for a sampling of dimming levels shall be recorded. However, it is not clear if the entire reference lookup table will be created at this time.

The exact implementation for building the full lookup table is to be determined. There are two options. The first is to build the lookup table in its entirety during the initial calibration and the other is to build the lookup table at night during an unoccupied period without the use of the desktop tool. The desktop tool would not be available because the concept is that only a small number, possibly only one, is required for a given project. Therefore, to require the desktop tool be assigned overnight to a photosensor would limit the nighttime lookup table function to one photosensor a night.

To determine when to start the unattended nighttime lookup table function, the photosensor could monitor when the controlled lights have been switched off, presumably by the termination of occupancy, and when there is no daylight. It could wait 15 minutes and then command the controlled lights on using the Force On command. In this option, only the photosensor light level readings would be recorded in the lookup table because the desktop tool would not be available to provide desktop illuminance readings.

Option 1 – Create the reference lookup table during the calibration process

Advantages	Disadvantages
Desktop tool will be present so task level illuminance readings are available.	Presence and changeability of daylight can reduce accuracy
Entire calibration process is completed at one time. No waiting for improved performance or calibration data.	Speed, while possibly sacrificing accuracy, is essential both to minimize calibration time and to reduce likelihood of daylight conditions changing. Time required to stabilize is not known at this time.
Results are available immediately for calibration report. No need to return to the photosensor location.	
Easier to have normally operating peripheral light sources on such as task lamps or undimmed lights in adjoining zones.	

Option 2 – Complete the reference lookup table following the calibration process during unattended period

Advantages	Disadvantages
Conditions are typically constant because daylight is not present. Easier to get more accurate readings.	No desktop illuminance information
Speed is not important. Lamps can be given adequate time to stabilize their output. Accuracy can be valued over speed.	Possible photosensor performance difference between before and after lookup table has been built. This may be a problem because the most careful performance scrutiny is likely to be immediately following setup and calibration.
The photosensor could repeat this process every three months to rebuild a new lookup table to compensate for dust and lamp depreciation .	Operation could be scuttled if unwanted lights shine into area because photosensor would never see the area as dark. An example might be an exterior light shining through a window.
	Very difficult to coordinate having peripheral light sources turned on during the test.
	Lights switching on may be reported as erratic and unexplained behavior.
	Completely unsupervised and anything could go wrong. Hard to anticipate all possibilities.

The exact implementation of the lookup table function will be determined during operational testing, possibly in some combination.

Looking Forward

The next phase of this research project is to build a prototype and then report on the ability to prove the concept. TWS will continue to refine the prototype and begin first laboratory tests followed by field testing.

This specification does not represent a commitment to build a prototype of this exact device. Rather, it is the best guess of what needs to be done and what can be accomplished. It is meant as a starting point for the lab, field and application testing. It is anticipated that some elements of this specification will be found to be unworkable and others will be further enhanced in a way not anticipated when this specification was written.

In this specification, some features have been identified as desirable but likely beyond the scope of this project. These items have been labeled as "future" enhancements. These enhancements are included to provide an overall concept for a fully implemented device that may or may not ever be constructed. It is anticipated that additional items written within this spec that are found not to be essential to the proof of concept may also not be implemented under this project.